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Arizona Chaparral: Plant Associations and Ecology

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Abstract

Plant associations within the Arizona chaparral were delineated by a hierarchical classification using a diversity change index. Climax associations are mountainmahogany (birchleaf or hairy) - mixed shrub, shrub live oak - hairy mountainmahogany, shrub live oak-birchleaf mountainmahogany, shrub live oak-mixed shrub, Arizona cypress-shrub live oak, and Arizona oak-yellowleaf silktassel-Emory oak. Fire induced climax associations are shrub live oak-datil yucca-yellowleaf silktassel, pointleaf manzanita, Pringle manzanita, and yerbasanta-desert ceanothus.

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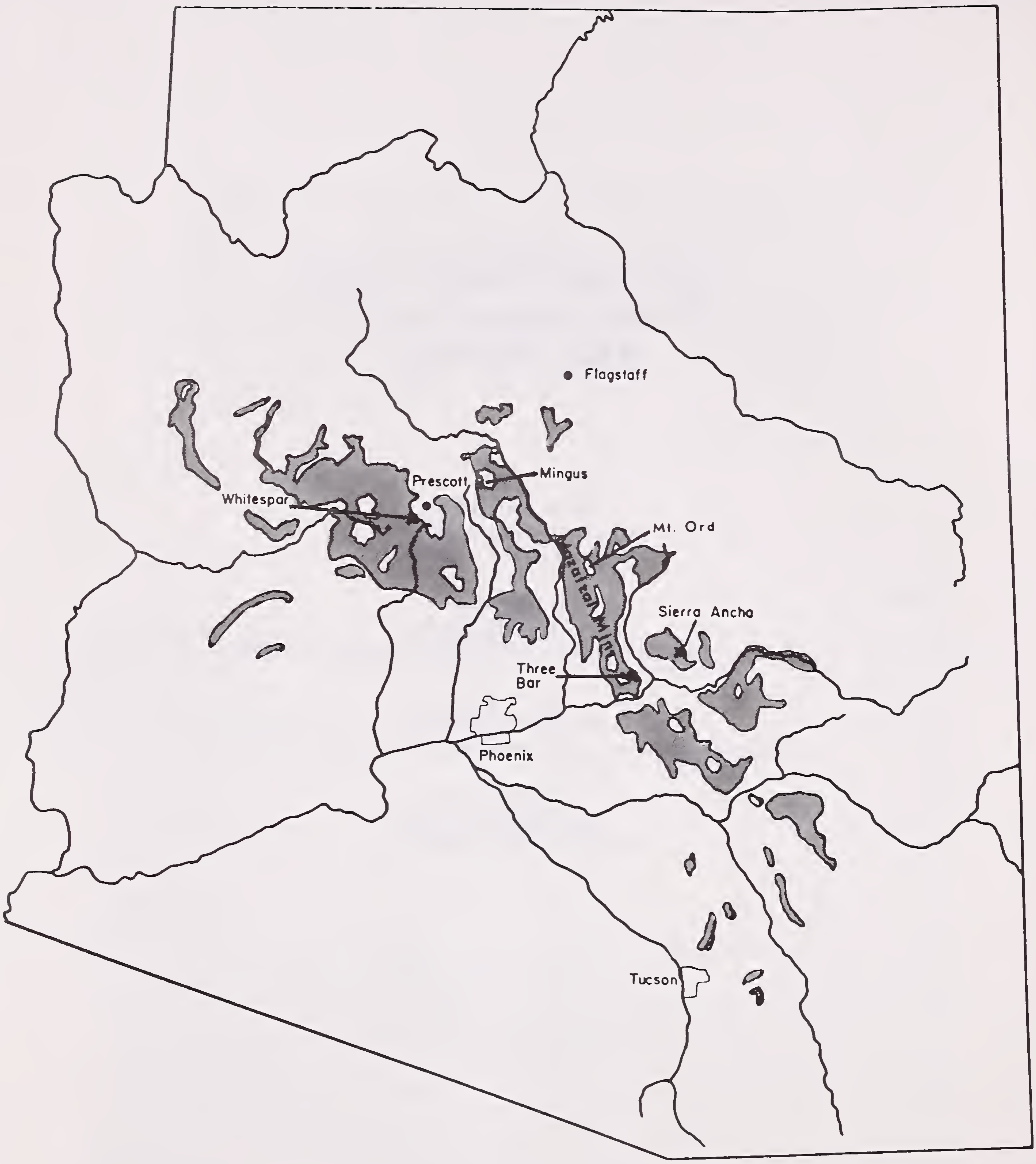

Figure 1.—Distribution of the chaparral vegetation type in Arizona (shaded), location of the study area (Mazatzal Mountains), and other research sites.

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Management Implications

The rapid increase of Arizona's population in recent years has created a need for more intensive management of the State's natural resources. Arizona's chaparral vegetation type represents an important resource providing water, wildlife forage, and recreational values. Historically, this vegetation type has been managed as a single floristic unit. Because of pressure for more intense management of the type, a more detailed plant community classification system is needed for use as a planning aid. The diversity of chaparral species results in several plant associations which together form the type or "series". Land managers should consider characteristics and responses of each association in the formulation of management strategies designed to obtain optimum use from the type as a whole. If this is to be accomplished, an understanding of the ecological interrelationships within and among associations is necessary.

Introduction

Because there is little uniformity in the use of ecological terms and concepts, the following definitions are used in this report. "Climax vegetation" is that which has reached a steady state with its environment, and is able to maintain itself through successive generations without external controls. "Seral communities" are vegetation units that have not reached such a steady state, and will, in the absence of external ecologic pressure, give way to vegetation types that are competitively better adapted to the macroclimate of the area. This is equivalent to the "associes" of Weaver and Clements (1938). All stands of climax vegetation that have similar overstory and understory dominants are considered belonging to the same "plant association". Although considerable variation may occur, it is wholly due to random factors, not to differences in the physical environment.

There is little information in the literature dealing with associations within Arizona chaparral. Swank (1958) recognized four: (1) shrub live oak-skunkbush, (2) shrub live oak-mixed shrub, (3) manzanita, and (4) mountain-mahogany.[2] Working in the chaparral and mountain browse type of Cochise County, Darrow (1944) also delineated four sub-types: (1) bear-grass, (2) mountainmahogany, (3) desert ceanothus, and (4) mixed shrub. Brown and Lowe (1974) recognized five: (1) manzanita, (2) ceanothus, (3) mountainmahogany, (4) shrub live oak, and (5) mixed scrub. Nichol (1952) noted that manzanita forms dense thickets of relatively large extent in some areas of the Arizona chaparral.

[2]Scientific names are given in the Appendix. Generally, common names of forbs and shrubs follow Kelsey and Dayton (1942); scientific names of forbs and shrubs follow Kearney and Peebles (1960), and common and scientific names of grasses follow Hitchcock (1950).

Objective

The objective of this study was to delineate associations within the Arizona chaparral and describe each in terms of associated species and other ecological factors.

The Chaparral Type

Definition and Extent

The term "chaparral" is derived from the Spanish word "chaparro," referring to dwarf evergreen oaks (Shantz 1947).

Arizona chaparral occurs mostly on the rough broken terrain south of the Mogollon Rim, extending generally in a discontinuous band across the State from the vicinity of Seligman in the northwest to Safford in the southeast (fig. 1). The type occurs at elevations

ranging from 915 to 1,830 m depending on exposure, soils and climate. The most extensive and continuous stands occur on or adjacent to the Prescott and Tonto National Forests, and on Indian lands in the Salt River Basin. The upper limits border ponderosa pine or pinyon-juniper, while the lower limits border desert grassland or southern desert shrub. In southeastern Arizona, chaparral mixed with oak-woodland adjoins ponderosa pine on the flanks of isolated mountain ranges (Lowe 1964).

The area covered by chaparral in Arizona has been estimated as large as 2.34 million ha (Nichol 1952). However, more recent surveys indicate less area. Spencer (1966) estimated 1.5 million ha, and Humphrey (1963) and Brown (1973) estimated 1.3 million ha in the State. These differences, particularly between Nichol's and the more recent surveys, reflect a lack of common criteria for classification.

We believe the more recent estimates are the most accurate; thus it is probable that chaparral covers less than 1.6 million ha.

Vegetation

Chaparral consists of deep-rooted evergreen broad-leaved sclerophyllous shrubs and trees that reach best development on deep soils or on deeply weathered or broken rock mantles.

Shrub canopy cover may vary from less than 40% on dry sites to more than 80% on the wetter sites. Herbaceous cover is virtually nonexistent when shrub cover approaches 60%. Annual litter production under oak and mountain-mahogany may reach more than 2,200 kg per ha (Pase 1972). Accumulated litter on the "forest floor" was more than 46,200 kg per ha under dense manzanita stands (Glendening and Pase 1964).

According to Pond and Bohning (1971), 50 or more shrub species occur in the chaparral vegetation zone in Arizona, but fewer than 15 are generally important in terms of density or animal use. Stands may consist of a heterogeneous mixture of many shrub species, or only one or two species (Nichol 1952).

Most of the species are prolific crown and/or root sprouters and produce few seedlings (Pase 1969); the few nonsprouters produce abundant seed. The sprouting species live to considerable age; Pond (1971) found little change in individual plants after 47 years.

Where shrub canopy is open to moderate, grasses and forbs may occur in intershrub spaces. Common native grasses are sideoats, hairy and blue grama, three-awns, cane bluestem, plains lovegrass, green sprangletop, wolftail, and muhlys. Weeping, Lehmann and Boer lovegrass are common in many areas where they have been introduced by seeding. Spring- and summer-growing annuals, abundant in favorable wet years, include red brome, witchgrass, sixweeks, and needle grama. Common forbs include penstemon, redstar morning-glory, dark spurge, mustards, buckwheats, asters, fleabanes, and bluedicks. Common half-shrubs are Wright buckwheat, broom snakeweed, rough menodora, and broom menodora.

The dominant and associated shrub species are discussed in the results section.

Climate

Mean annual precipitation ranges from 400 mm at the drier limits of the Arizona chaparral to more than 650 mm on the wetter sites. Elevation alone is not a good indicator of precipitation. Precipitation generally increases with elevation, but the relationship is not always uniform. The proximity of mountains and other physiographic factors that control flow and cooling of air combine with elevation to produce local climates.

Annual precipitation is characterized by two distinct wet periods. About 55% occurs during the cool winter months (November through April). Some snow occurs each year, but normally snow is not an important factor. About 35% of the annual precipitation occurs in the form of local convection rainfall during July, August, and September. October, May, and June are the driest months; only about 10% of the annual precipitation comes during these months.

Mean annual precipitation is commonly used to describe the moisture regime of an area. By itself, however, the mean tells nothing about the frequency and seasonal distribution of rain, and little about the magnitude of dry and wet years, critical factors in the survival and maintenance of plant cover. Long-term records for the chaparral are scarce, but available data suggest that the driest years receive about one-half the mean precipitation, while the wettest years get about double the mean. Thus, in some marginal areas, as little as 200 mm of rain may

fall in dry years, while in very wet years, the wetter sites might receive as much as 1,200 mm.

Soils and Geology

Soils supporting chaparral have certain characteristic properties throughout central Arizona. Typically, soils are deep, coarse textured, and poorly developed. Soil includes all porous material (regolith) in which weathering and roots are active. The distinction between soil depth and solum depth (A and B horizons) is critical in this case, since most of the soil is in the C horizon. Soil surveys which describe the soil as shallow generally pertain to solum depth. Usually, the A horizon is only a few inches thick, and the B horizon is commonly absent. Soil texture varies from cobbly and gravelly loamy sand to gravelly loam.

Parent materials include deeply weathered and fractured granite, schist, diabase, sandstone, shale, limestone, slate, gneiss, quartzite and basalt. Granites are found on more than half the total chaparral area; no one of the other types make up more than 10%; schist derived soils are probably the second most common. Rock types such as basalt, limestone, quartzite, shale and slate, which weather to fine-textured and shallow regoliths, do not support extensive stands of chaparral, even though rainfall and elevation are often favorable. These soils usually support juniper and pinyon or grass. Examples of chaparral on granite adjacent to juniper on basalt can be found on the Tonto and Prescott National Forests.

The view that the distribution of chaparral and juniper is more a function of soil than climate and elevation has not been widely held. Juniper has been assumed to occur at higher elevations and in a higher rainfall zone, however, this assumption is not valid. For example, Utah, one-seed, and alligator juniper dominate the central portion of the Beaver Creek drainage south of Flagstaff, at elevations ranging from 1,500 to 2,000 m, where average annual precipitation is 457 to 508 mm. On Mingus Mountain, 48 km to the southwest, at the same elevation and precipitation, chaparral is the dominant vegetation. Soil is the only apparent difference in the sites that would account for the difference in vegetation. The soils on Beaver Creek are derived from basalt and are fine textured and shallow, compared with the soils on Mingus Mountain which are derived from metamorphic sedimentary rock that is shattered and deeply weathered. The reasons for these differences are not readily apparent. We are inclined to think that soil depth, texture, and/or temperature (juniper-dominated areas are cooler than chaparral) may all be important. Dense stands of chaparral on fine textured soils (derived from basalt, shale and slate) are rare, but they do occur. We suspect that in these situations the area may be too warm for juniper, and/or the parent material is fractured to greater than usual depths and thus more suited to the deep rooted chaparral.

Successional Status

The successional status of chaparral has been a point of debate for many years. It has been hypothesized that chaparral was either an artificial subclimax caused by repeated fire (Clements 1920), or a transitional type of vegetation which, if not for recurring fires, would eventually be replaced by trees (Jepson 1925, Horton 1950). In Clements' later writings, he recognized chaparral as a true climax that persists after recurrent fires, stating that the chaparral type is a stable shrub community lying below a belt of subclimax chaparral occupying sites once held by coniferous forests (Weaver and Clements 1938, Allred and Clements 1949). This latter view is the one that has come to be most widely accepted.

Adaptation to Fire

Axelrod (1958) states that fire has influenced the evolution of chaparral species since the Miocene Era. As a result of natural selection, adaptations have developed which prevent the elimination of chaparral species by fire. These adaptations include: (1) production of seed at an early age; (2) fire-resistant seeds; (3) seeds dependent on fire for germination; (4) production of seeds in such large numbers that some survive even though the heat destroys many; and (5) sprouting from latent buds mainly below ground (Hanes 1970).

The type is well adapted to fire. Because the well-developed root systems draw moisture and nutrients from a large volume of soil, stands regenerate rapidly following fire (Pond and Cable 1962; Pase and Pond 1964; Pase and Lindenmuth 1971). Favorable weather conditions germinate seeds of nonsprouting species, such as ceanothus and manzanita, which, under natural conditions, do not germinate in the absence of heat scarification (Pase 1965).

In contrast with other vegetation types, secondary succession in chaparral after fire is not a series of vegetational replacements but a gradual ascendance of long-lived species present in the prefire stand (Hanes 1970). Cable (1957) observed that sprouting shrubs regained densities that approximated shrub densities on adjacent unburned areas within 5 years after burning. Pond and Cable (1962) found that chaparral crown cover approached that of nearby unburned sites within 7 years after burning. Pase and Pond (1964) observed that, at the end of six growing seasons, a burned chaparral site in Arizona had regained three-fourths of its original cover, and that, in a period of 5 years, seedlings of nonsprouting chaparral shrubs (those which produce seeds whose germination is increased by heat scarification) were numerous. In an oak-mountainmahogany stand, where fire reduced shrub cover from 59.1% to 3.5%, shrub cover regained 76% of its prefire status after 5 years (Pase and Lindenmuth 1971). Tiedemann and Schmutz (1966) found that, on a chaparral site which was burned and seeded to weeping lovegrass, shrub live oak cover was reduced for 8 years, but that shrub competition was so severe that grass growth was virtually nil after 5 years. Hanes and Jones (1966) pointed out that, after a fire on a chaparral site, postfire vegetation was composed mainly of root-crown sprouts and seedlings of prefire species. They noted that overall shrub composition remained relatively constant after fire, although relative abundance of species changed, and seedlings of nonsprouting species regenerating from seed were influential in stand succession.

Rates of recovery of individual shrub species after fire are dependent on their sprouting ability, ability to establish seedlings, their relative abundance in the prefire stand, and possibly the time of year of the burn (Cable 1975). In some cases, 11 years or more are required for shrub cover to reach preburn levels (Hibbert, Davis and Scholl 1974). The fire adaptation characteristic of the various woody species of the Arizona chaparral are presented in the Appendix.

Methods

This study was conducted in the Mazatzal Mountains in the heart of the Arizona chaparral. The Mazatzals extend from northwest to southeast, approaching the Mogollon Rim to the north and paralleling Roosevelt Lake to the south. The Mazatzals are characterized by steep, rugged slopes and numerous canyons. Slopes of 60% to 70% are common.

A reconnaissance of the study area was conducted before sampling. Forty stands were selected on the basis of: (a) no obvious disturbance factor present, such as excessive grazing, mechanical or other disturbance, (b) relatively uniform slope and aspect, (c) far enough from road or trail to be unaffected by it, (d) a single vegetative type, (e) at least 10 years of age, and (f) on a single soil type. Several stands of every chaparral vegetation mix in the study area were sampled. A stand was considered to be any area of sufficient size to accommodate the sampling technique, that exhibited a homogeneous vegetative type. Care was taken to avoid transition zones between types. The data were analyzed, and a preliminary classification of associations[3] was established. Several years later, a second reconnaissance was conducted, and 35 additional stands were selected to better represent associations previously undersampled and to include associations with species composition not accounted for in the preliminary classification. Thus, a total of 75 stands were sampled.

Determination of plant composition and cover in the first 40 stands sampled was made at 10 randomly located points within each stand. From each point four quadrats were created by the use of a 1.5-m staff marked in 0.3-m intervals. Thus, each quadrat was 1.5 m on a side, making the area of each quadrat 2.25 m^2. With the aid of the 1.5-m staff, ocular estimates of shrub and half-shrub canopy cover in m^2 were determined by species for each quadrat[4]. Estimates from the four quadrats were totaled to give shrub cover by species per 9 m^2, and a preliminary classification was developed on the basis of these estimates.

The final 35 stands were sampled by use of five 30-m line intercepts within each stand. A point was selected at random for the start of the first line in a stand, and a 30-m tape was stretched from that point across the slope over the tops of the vegetation to be described. Cover data

[3] *Terminology used, e. g., association, seral stage, climax, etc. conform to "Modified Ecoclass, A Method for Classifying Ecosystems," unpublished file data, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80521.*

[4] *For ease of presentation, half-shrub cover, which contributes relatively little, is combined with and discussed as shrub cover in the text; half-shrub cover is shown separately in the tables.*

were recorded by species on the basis of the length of canopy intercepted by the tape. After the first line was completed, the tape was moved 15 m downslope, and the procedure was repeated until five lines had been completed.

Several stands of the first 40 were resampled using the line intercept method and variation between the two methods was less than the variation encountered within the association as a whole. The stands resampled were grouped into the same associations with a high degree of similarity by both methods of sampling. Therefore, it was concluded that both methods would give reliable and consistent information. However, for workers less familiar with the chaparral and less experienced in sampling, the line intercept method is advantageous because of its objectivity. The workers who collected data on the first 40 stands were no longer available when sampling began on the second group of 35 stands. Because of the discontinuity in field personnel, the decision was made to shift to the more objective line transect method.

Analysis

Associations were delineated by a hierarchical classification utilizing a diversity change index (Bonham and Brady 1973). The dendrogram obtained from hierarchical analysis (fig. 2) illustrates interrelationships of the 75 stands based on vegetative composition and cover of individual stands. The higher the change in information at which stands are joined, the more dissimilar the stands are; this also applies to the joining of groups of stands. Vegetation types or associations within types are seldom neatly segmented nor defined by sharp boundaries, but gradate in a continuum in response to changes in environment. When using an objective quantitative analysis procedure, such as the one used here, results must be tempered by subjective judgment based on

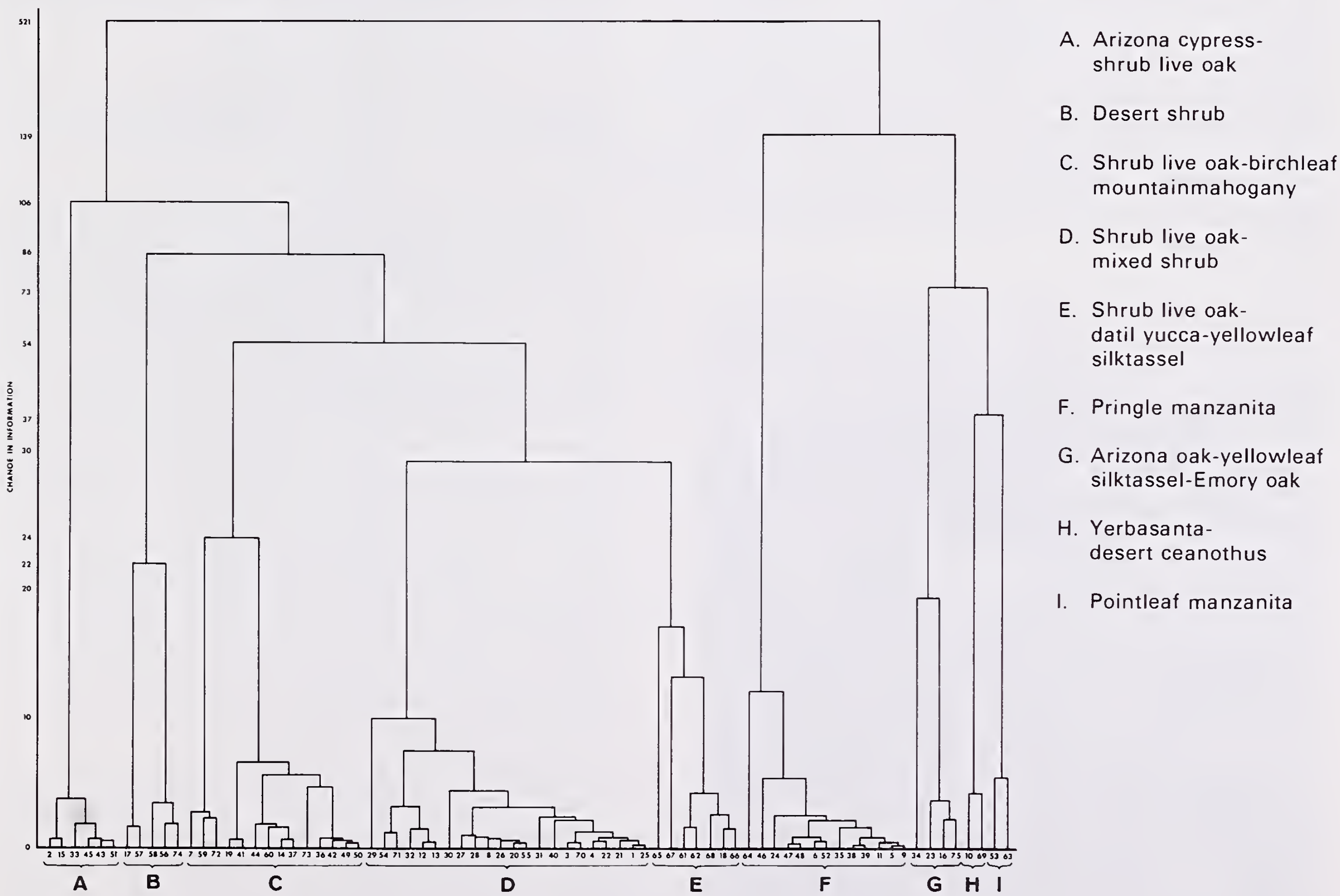

Figure 2.—Hierarchical groupings of chaparral associations in the Mazatzal Mountains of central Arizona. The second grouping from the left consists of five lower elevation stands on the fringe of the chaparral. These stands are not discussed further because other species dominated and thus these were not true chaparral communities.

field observations. Thus, for ease of comparison, the community approach was used to categorize the vegetation into eight associations. The stands were grouped into associations according to similarity in cover values by species. Associations were then named (after the stands had been grouped) after those species which had high importance in the type, i.e., high cover and constancy. The order of the species within the name is indicative of their relative average percent canopy cover.

Communities

Shrub Live Oak - Mixed Shrub

This association (fig. 3) had the widest ecological amplitude of any identified, and occupied more sites (22 of the 75 stands) than any other. This tends to substantiate our assumption that shrub live oak is the most frequent dominant throughout the Arizona chaparral. This association occurred on all exposures but southwest (it also occurs on southwest exposures, but none were present in this study), at elevations ranging from 884 to 1,661 m, and on slopes ranging from 5% to 50%. Topographic positions on slopes (percent distance from toe to crest of slope) ranged from 10% to 99%.

Figure 3.—Shrub live oak-mixed shrub community.

The association mix was made up of 37 species, but only shrub live oak had 100% constancy. More shrub and half-shrub species were encountered in this association than in any other (table 1).

Shrub cover of the 22 stands averaged 58.9% of which 36.4% was shrub live oak. The second and third most important species in this association were the half-shrub broom snakeweed, 58.2% constancy and 1.4% cover, and sugar sumac, 54.5% constancy and 2.2% cover.

The association occurred on a wide variety of soils. Most of the stands were on soils derived from granite and basalt; schist, limestone and shale were also represented.

Fourteen percent of the stands burned in 1974, 18% in 1959; 68% have no recent fire history.[5] We consider this association climax because shrub live oak sprouts and regenerates rapidly. There was no evidence, even in the oldest unburned stands, that the dominant species were threatened by replacement by "higher" successional species.

Shrub Live Oak - Birchleaf Mountain-mahogany

The shrub live oak - birchleaf mountain-mahogany association (fig. 4), except one stand at 1,700 m, occurred at elevations ranging from 975 to 1,280 m. Slopes and topographic positions on slopes were variable. Slopes ranged from 7% to 70% and topographic position on slopes ranged from 40% to 99%. The association was found primarily on north exposures and dominated 14 of the 75 stands observed; it was the second most abundant of the 8 identified. This association has a counterpart in the shrub live oak-hairy mountainmahogany association over a substantial portion of the Arizona chaparral. Also, one of the mountainmahogany species may occur as the only dominant on wetter, southerly slopes in the drier reaches of the Arizona chaparral (mountainmahogany-mixed shrub association).

The following discussion is applicable to all three of the associations where one of the mountainmahogany species is dominant or codominant. The reader should keep in mind that, although only eight were delineated by this study, there are a total of 10 important

[5] *Fire history was determined from Tonto National Forest maps that date to about 1910. Any stand not falling within a region having burned since this time is considered as having "no recent fire history."*

Table 1.—Cover and constancy of the Arizona chaparral associations

Species	Shrub live oak-birchleaf mountainmahogany		Shrub live oak-mixed shrub		Arizona cypress-shrub live oak		Shrub live oak-datil yucca-yellowleaf silktassel		Arizona oak-yellowleaf silktassel-Emory oak		Pringle manzanita		Yerbasanta-desert ceanothus		Pointleaf manzanita	Total no. of stands
No. of stands	14		22		6		7		4		13		2		2	90
Species	Constancy	Aver. Cover	Constancy	Aver. Cover	Constancy	Aver. Cover	Constancy	Aver. Cover	Constancy	Aver. Cover	Constancy	Aver. Cover	Constancy	Aver. Cover	Constancy	Aver. Cover
Alligator juniper			4.5	.1					25.0	1.6	30.8	.7				
Arizona cypress	7.1	0			100.0	36.9					38.5	1.7				
Arizona oak	7.1	.4	4.5	.1			85.7	4.8	100.0	32.5	38.5	2.0			50.0	2.4
Baker serviceberry			4.5	.0					75.0	4.1	7.7	.0				
Birchleaf mountainmahogany	100.0	17.1	31.8	1.8	16.7	.8	42.9	1.6					50.0	9		
Broom menadora			9.1	.1												
Broom snakeweed	42.9	1.3	68.2	1.4									50.0	2.0		
California brickellia	7.1	.0														
California buckthorn									25.0	.0	7.7	2	50.0	.4		
Canyon live oak							28.6	1.7								
Catclaw	21.4	.5	22.7	.6											50.0	.6
Catclaw mimosa	14.3	1	40.9	1.6			14.3	1			15.4	1	50.0	.7		
Datil yucca	42.9	.4	27.3	.4	50.0	.7	100.0	5.1	25.0	4	7.7	.0	50.0	2	50.0	.3
Deerbrush ceanothus	7.1	.0	4.5	.0			14.3	2			15.4	2.2				
Desert ceanothus	78.6	4.1	59.1	2.4	83.3	2.3	57.1	1.8	25.0	.2	76.9	3.1	100.0	11.4	100.0	5.6
Emory oak	14.3	.5	13.6	.2			85.7	16.2	100.0	7.7	92.3	8.6	50.0	1.0	100.0	5.8
Engelmann pricklypear			9.1	.1	33.3	3	14.3	0								
False mesquite			13.6	2					25.0	.4						
Feather dolea			9.1	.1												
Gambel oak									50.0	4.3						
Hollyleaf buckthorn	50.0	1.0	45.5	1.0	16.7	.3	71.4	1.0	50.0	.3	7.7	.1	100.0	1.2		
Littleleaf krameria	21.4	.5	9.1	.1												
Lowell ash	14.2	.1	9.1	.0									50.0	2.7		
Netleaf hackberry			4.5	.0												
New Mexico locust									25.0	5						
One-seed juniper			18.2	1.0												
Palmer oak	14.3	.3							25.0	1.5						
Parry agave			13.6	.1					50.0	.1						
Pinyon					33.3	1.6			50.0	4	23.1	.2				
Pointleaf manzanita	14.3	.7	50.0	3.0	50.0	1.4	85.7	3.0	50.0	.9	46.2	1.9	50.0	.6	100.0	54.5
Ponderosa pine									50.0	10.7	7.7	.0				
Pringle manzanita	14.3	.1	18.2	2.0	50.0	1.5	14.3	.1	25.0	.9	100.0	55.2	50.0	1.0	50.0	9.0
Purple nightshade	14.3	.1	4.5	.0												
Redberry algerita	7.1	.0	18.2	.3												
Sacahuista			40.9	1.2	16.7	1	28.6	1.1	25.0	.1	7.7	.1	50.0	.3		
Shrub live oak	100.0	24.1	100.0	36.4	100.0	25.6	100.0	28.2	50.0	3.0	69.2	2.1			100.0	2.3
Shrubby deervetch	14.3	.1	9.1	.1												
Skunkbush			63.6	1.8			14.3	.0	25.0	.3			50.0	.1		
Soaptree yucca			4.5	.0												
Sugar sumac	78.6	6.9	54.5	2.2	50.0	1.3	28.6	8	50.0	1.2	23.1	.2	50.0	.3	50.0	1.3
Wheeler sotol			4.5	.0												
Wright buckwheat	57.1	1.3	45.5	.6			42.9	4.8					50.0	2.2		
Wright silktassel	14.3	1.4	9.1	.1			28.6	1.8	25.0	1	38.5	.7	50.0	.1	50.0	2.0
Yellowleaf silktassel	28.6	1.6	22.7	.7	16.7	.4	100.0	4.3	100.0	11.1	15.4	1	100.0	.1		
Yerbadepasmo baccharis			4.5	.0												
Yerbasanta	35.7	1.7	13.6	.3			14.3	.0			7.7	2	100.0	25.2	50.0	2.5
Total Aver. Cover		64.3		58.9		73.2		76.6		82.2		79.5		50.4		86.2

Figure 4.—Shrub live oak-birchleaf mountainmahogany community.

Figure 5.—Arizona cypress-shrub live oak community.

associations and serial communities within the Arizona chaparral. Again, this substantiates an earlier belief that shrub live oak and the mountainmahoganies are the most frequent codominants of the Arizona chaparral.

A total of 27 shrub species occurred; it was second only to shrub live oak-mixed shrub in variety of species. The only species with 100% constancy were shrub live oak and mountainmahogany (table 1). Shrub canopy cover of the 14 stands averaged 64.3%, of which 52% was made up by four species—shrub live oak 24.1%, mountainmahogany 17.1%, sugar sumac 6.9%, and desert ceanothus 4.1%.

Eleven stands occurred on granite, two on schist, and one on slate derived soils.

Twenty-nine percent of the stand grouped into this type burned in 1947, 50% in 1959, and 21% have no recent fire history. Stands that burned in 1959 have cover and composition comparable to stands with no recent fire history; thus, rapid recovery following fire is evident; the codominants sprout prolifically. There is no evidence that this association will be replaced; we consider it climax.

Arizona Cypress - Shrub Live Oak

This association (fig. 5) occurred at elevations ranging from 1,250 to 1,463 m and on slopes ranging from 4% to 55%. It demonstrated the least ecological amplitude of any association identified by the study. The validity of placing this association in the Arizona chaparral is questionable because the major dominant, Arizona cypress, is a tall tree. However, the association occurs within the heart of the chaparral, and the associated species truly belong to the type. It was found only in the vicinity of Mt. Ord in the northern part of the study area, primarily on wet north slopes, and generally occurred on the upper portions of slopes, although positions on slopes ranged from 25% to 99%.

The association was found on soils derived from slate, schist, limestone, and granitic parent materials. This variety of soil parent materials and no clear preference for either indicate that its distribution is due to climatic rather than edaphic factors.

Canopy cover of the six stands averaged 73.2% of which the 2 dominants, Arizona cypress and shrub live oak, made up 36.9% and 25.6%, respectively. Both of these species had constancies of 100% (table 1). Arizona cypress forms closed stands and precludes the occurrence of understory over considerable portions; other species occur primarily where not overshadowed by the trees. Other species which occurred were sugar sumac, desert ceanothus, and pringle and pointleaf manzanitas.

None of the stands have a recent fire history. The size and age of the cypress trees support this fact. Large numbers of trees 9 to 12 m in height were present; since Arizona cypress is a nonsprouter, we consider these to be relatively old trees and that this is a climax association.

Shrub Live Oak - Datil Yucca - Yellowleaf Silktassel

This association (fig. 6) occurred at elevations ranging from 1,097 to 1,737 m on slopes ranging from 15% to 35%. Position on the slope ranged from 20% to 80%. The community showed a propensity to occupy the wetter north and east exposures.

The three dominants had constancies of 100%. Average cover of the seven stands was 76.6% of which shrub live oak made up 28.2%, datil yucca 5.1%, and yellowleaf silktassel 4.3%. The most common of the less important species were Emory and Arizona oak, pointleaf manzanita and Wright buckwheat (table 1). All stands of this community occurred on soils derived from granite.

All stands grouped in this community were burned in 1959. This community probably represents a fire induced climax, as Emory oak was prominent in the communities (constancy 85.7% and average cover 16.2%). It is likely that Emory oak will eventually assume the role of codominant along with shrub live oak, silktassel and other low growing shrubs which are now dominant because their post fire recovery is more rapid than Emory oak.

Arizona Oak - Yellowleaf Silktassel - Emory Oak

This association (fig. 7) was found at elevations ranging from 1,646 to 1,768 m. Exposures varied, but in general were some of the wettest sites sampled. Slope varied from 33% to 43%, and topographic position on slope ranged from 60% to 80%.

A total of 23 shrub species occurred in this association; it ranked third in variety of species. Canopy cover averaged 82.3%, of which 32.5% was Arizona oak, 11.1% yellowleaf silktassel, and 7.7% Emory oak; all of these species had constancies of 100%. Other species worthy of note were Gambel oak, ponderosa pine, and serviceberry (table 1). This community often bordered the pine type. The four stands were all found on soils derived from different parent materials—granite, schist, shale, and slate. Since percent canopy cover was second highest of the eight associations identified in the Mazatzal Mountains, it is obvious that relatively closed stands of chaparral may be found on a wide variety of soils.

None of the stands have a recent fire history. The Arizona oaks are large enough to indicate a relatively long period since fire. Since there are

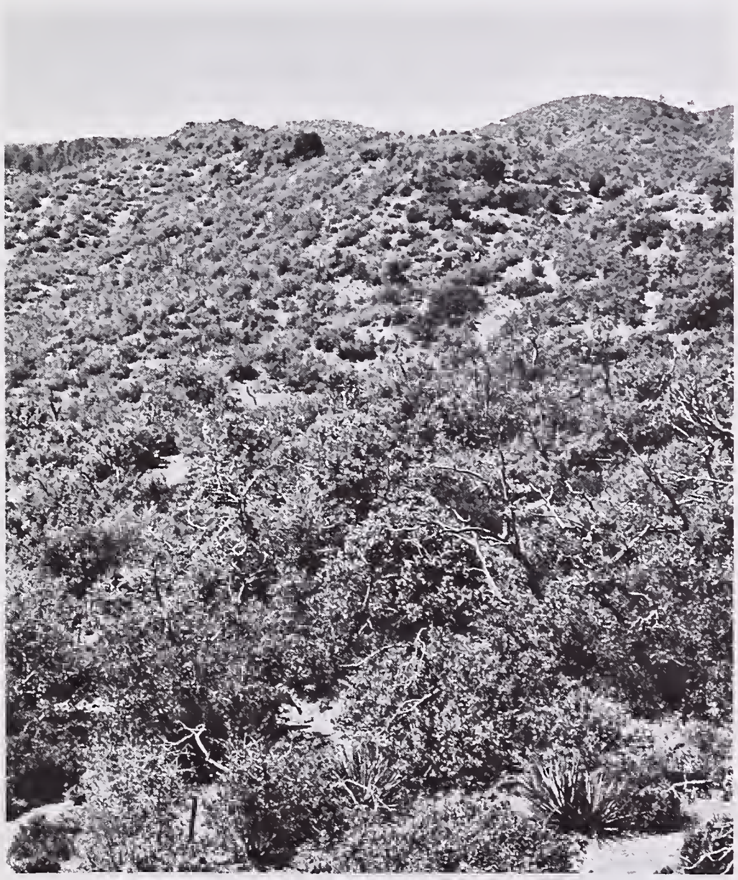

Figure 6.—Shrub live oak-datil yucca-yellowleaf silktassel community.

Figure 7.—Arizona oak-yellowleaf silktassel-Emory oak community.

no species within the stands capable of replacing the Emory and Arizona oak, we believe this community represents climax; some fluctuation in the ecotone between this association and the ponderosa pine type above may occur as a result of grazing, fire, or climatic fluctuations.

Pringle Manzanita

This association was found at relatively high elevations, 1,433 to 1,737 m (fig. 8). It generally occupied a belt below the Arizona oak-yellowleaf silktassel-Emory oak association. These stands were usually high up (70% to 90% topographic position) on gentle slopes (5-40%) of predominantly northerly aspect.

A total of 21 species occurred in this community, but only the manzanita had a constancy of 100% (table 1); of the average canopy cover of 79.5%, 55.2% was manzanita; the second most important species was Emory oak which averaged 8.6% cover. Canopy cover of desert and deerbrush ceanothus, the species with third and fourth highest cover, was only 3.1% and 2.2% respectively; average cover of other species was 2.1% or less. Although Emory oak had a constancy of only 92.3% and made up only 8.6% of the cover, it was of considerable importance. Even in almost pure stands of Pringle manzanita, scattered individuals of Emory oak were overtopping the manzanita and exerting an influence; the influence can be expected to become somewhat more marked as their height and canopy spread increases.

Of the 13 stands, 5 occurred on granite, 5 on schist, 2 on shale, and 1 on gneiss-derived soils.

We consider this a fire induced climax association. Pringle manzanita reproduces only from seed that requires heat scarification for germination; in the absence of fire, these sites would eventually be replaced in the stand. However, only four of the stands have a recent history of fire; the oaks in the stands were sparse, and no seedlings were found. There are, however, manzanita stands where Emory oak or Arizona cypress are probably climax. On a north-facing slope of Mt. Ord (fig. 1) fire apparently altered what was once an Arizona cypress association.[6] This site is now dominated by a dense stand of manzanita, but Arizona cypress saplings have emerged through and are beginning to overtop the manzanita (fig. 9). No doubt the manzanita-Arizona

[6]*Forest Service records do not show this area as having burned, but charred stumps of Arizona cypress were present.*

Figure 8.—Pringle manzanita community.

Figure 9.—Arizona cypress replacing a Pringle manzanita-Emory oak community.

cypress is a seral stage in this situation, and barring the occurrence of fire, the site will eventually be dominated by Arizona cypress. The same may be true of the Pringle manzanita stands, for without fire, one or more of the more prevalent shrubs (e.g. the silktassel or shrub live oak) or trees (e. g. Emory or Arizona oak, juniper or Arizona cypress) would assume dominance.

Yerbasanta - Desert Ceanothus

The yerbasanta-desert ceanothus association (fig. 10) was represented by only two stands. Elevation of these two stands was 1,402 and 1,676 m. Both occurred on soils of granitic origin on the upper portions of 25% slopes. One was on a northeasterly and the other on a southwesterly exposure. The results of this study and other observations we have made indicate that the association can be found on any exposure but is restricted to upper slopes and/or relatively level sites where other shrubs are scarce.

Only 18 shrub species were present; four—yerbasanta, desert ceanothus, hollyleaf buckthorn and yellowleaf silktassel—had constancies of 100% (table 1). The buckthorn and silktassel were not included in the name because they made up only 0.1% and 1.2% of the 50.4% total canopy cover. Canopy cover of the dominants—yerbasanta and desert ceanothus—was 25.2% and 11.4%, respectively.

Only one of the stands has a recent history of fire, but the other has probably burned in the not-too-distant past. Seeds of both yerbasanta and desert ceanothus are long lived and are stimulated to germinate by heat (Pase 1965, and Glendening and Pase 1964). Also, yerbasanta sprouts prolifically from near-the-soil-surface lateral roots following burning of the parent plant. Yerbasanta has gained dominance over a small area, following two burnings at the Three Bar Experimental Watersheds (fig. 1), where it was scarcely present prior to the initial burn; desert ceanothus was nearly eliminated from the plot (Knipe 1977)[7]. Thus we believe that this association is a fire-induced climax. Should repeated fires occur before the ceanothus has produced seeds (believed to be at about 10 years of age), it would be largely eliminated from the stand, and yerbasanta would emerge as the shrub of most importance. However, we doubt that the ceanothus would ever be totally eliminated, as it is not likely that all of the seeds would germinate following a single fire.

Pointleaf Manzanita

This association (fig. 11) was represented by only two stands; pointleaf manzanita clearly dominated both (table 1). The stands occurred at 1,066 and 1,585 m on the upper portions of 20% slopes and on easterly exposures. Soils were of granite and quartzite origin.

[7]*Unpublished file data, Rocky Mountain Forest and Range Experiment Station, Tempe, Arizona 85281.*

Figure 10.—Yerbasanta-desert ceanothus community.

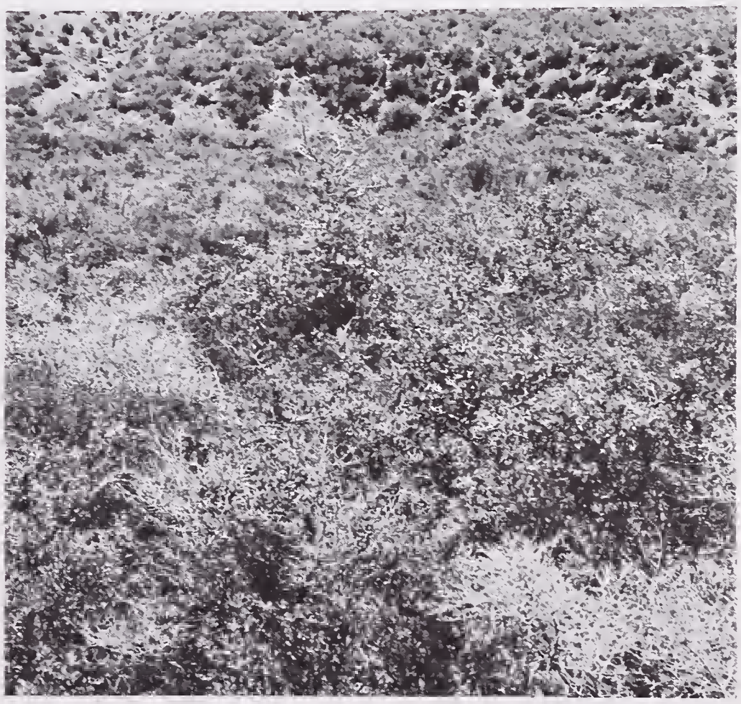

Figure 11.—Pointleaf manzanita community.

Only 11 shrub species were present. Total canopy cover was 86.3%, of which pointleaf manzanita made up 54.5%. Three other species—desert ceanothus, Emory oak and shrub live oak—were present in all samples (100% constancy), but their cover percentages were only 5.6%, 5.8% and 2.3%, respectively. This association appears to be the low elevation counterpart of the Pringle manzanita community; apparently pointleaf manzanita is better adapted to the drier, warmer sites, as only 9% of the canopy cover consisted of Pringle manzanita. Both of these stands have a recent history of fire, so the manzanita have no doubt regenerated from seed. We consider this a fire-induced climax association because pointleaf manzanita is relatively short-lived and, as Pringle manzanita, reproduces only from seed, which require heat scarification for germination. In the absence of fire, the manzanita would eventually be replaced by shrub live oak - mixed shrub or, where moisture is adequate and they are present in sufficient numbers, Emory and/or Arizona oak.

Arizona vs. California Chaparral

Much of the literature related to chaparral vegetation deals with the type as it exists in southern California. Structure and species of Arizona and California chaparral are similar, but there are differences worthy of note. Clements (1920) noted that growth of California chaparral occurs primarily during the winter months, as contrasted to a summer growing season in the Petran (Arizona) chaparral. He described the Petran chaparral as winter deciduous. As late as 1970, Hanes referred to the Petran chaparral type as deciduous. In reality, Arizona chaparral is, by definition, evergreen broad sclerophyll shrub lands (Hibbert et al. 1974). Cable (1975) points out that Arizona chaparral consists almost entirely of low-growing shrubs with thick evergreen leaves. Pond and Bohning (1971) state that, in Arizona, the leaves of most chaparral species remain on the plants throughout the winter until new leaves are well developed in the spring. The only deciduous shrub of importance in the Arizona chaparral, from the standpoint of frequency of occurrence, is skunkbush; the only other deciduous species that occurs with any appreciable frequency is the usually small tree Gambel oak. Skunkbush is never dominant, and Gambel oak dominates only locally on wet north slopes and along drainages.

The average daily maximum temperatures for the warmest and coldest months are similar in Arizona and California chaparral, ranging from about 31° to 37° and 10° to 14°C, respectively. Average annual precipitation varies greatly, in both amount and distribution pattern, between the two regions. Arizona chaparral receives about 400 to 660 mm precipitation annually, distributed approximately 55% in winter and 45% in summer (Hibbert et al. 1974). California chaparral receives about 660 to 915 mm precipitation annually, primarily during the winter (Mooney and Parsons 1973). The climate of the California chaparral is Mediterranean. The uniqueness of the Arizona chaparral climate separates it from other broad sclerophyll regions.

According to Axelrod (1958), both the California and Arizona chaparral types have a common origin in the Madro-Tertiary geoflora of the Cenozoic Era on the North American continent. He notes that the separation of the two types came in the late Cenozoic in response to major topographic-climatic changes producing the present climates of both types. The California chaparral was separated from the Petran chaparral and came under the influence of the present Mediterranean climate. With the source of summer precipitation cut out by new mountain ranges, competitive advantage was given to species better adapted to withstand the long, dry summers in the California type. The climate of the Petran chaparral was less modified and continued to receive summer rains, and more nearly approximates the Tertiary environment. As a result, there was less change in the original chaparral vegetation occurring in Arizona. Trees such as pine, juniper, and oak continued to be mixed in with the Petran chaparral as they probably were during the Tertiary.

Conclusions

Plant associations and seral communities delineated in this study are representative of those likely to be encountered in the Arizona chaparral. Shrub live oak-birchleaf mountain-mahogany, shrub live oak-hairy mountain-mahogany, shrub live oak-mixed shrub, and mountainmahogany-mixed shrub are the most extensive; well over 50% of the Arizona chaparral consists of these four associations. Other associations delineated by this study are: Arizona cypress-shrub live oak, shrub live oak-

datil yucca-yellowleaf silktassel, Arizona oak-yellowleaf silktassel-Emory oak, pointleaf manzanita, Pringle manzanita, and yerba-santa-desert ceanothus.

It is difficult to rank the latter six in importance. In terms of area occupied, all are relatively unimportant compared to the four most extensive associations. Yerbasanta-desert ceanothus is probably the least extensive, occurring only in severely disturbed areas, while those where manzanitas and Emory oak are dominant or codominant are slightly more extensive.

Over the region covered by this study the communities occurred at average elevations as follows:

Mountainmahogany-mixed shrub	*
Shrub live oak-hairy mountain-mahogany	*
Shrub live oak-birchleaf mountain-mahogany	1,150 m
Shrub live oak-mixed shrub	1,200 m
Pointleaf manzanita	1,300 m
Arizona cypress-shrub live oak	1,350 m
Shrub live oak-datil yucca-yellow-leaf silktassel	1,500 m
Yerbasanta-desert ceanothus	1,500 m
Pringle manzanita	1,600 m
Arizona oak-yellowleaf silktassel-Emory oak	1,700 m

*No elevation range available. These types, however, are found in the drier portions of the Arizona chaparral.

Thinking of Arizona chaparral communities in terms of elevation is often misleading; one should not expect to find these communities limited to these elevations throughout the Arizona chaparral. Their locations are governed primarily by precipitation and to some extent by topographic and edaphic factors; as noted previously, precipitation and elevation are not closely correlated.

Of the ten associations and seral communities delineated by this study, four are considered climax: shrub live oak-mixed shrub, shrub live oak-birchleaf mountainmahogany, Arizona cypress-shrub live oak, and Arizona oak-yellowleaf silktassel-Emory oak. Two others—shrub live oak-hairy mountainmahogany, and mountainmahogany-mixed shrub—not present in this study area, are also climax associations. Yerbasanta-desert ceanothus is a fire-induced climax community; climax for these sites is most likely to be shrub live oak-mixed shrub or shrub live oak-mountainmahogany. Pointleaf and Pringle manzanita reproduce only from seeds which have been heat scarified. In the absence of fire, the manzanitas would be replaced by shrub live oak-mixed shrub, or where moisture is adequate, one or more of the taller oaks or Arizona cypress. Shrub live oak-datil yucca-yellowleaf silktassel is a fire-induced climax; in the absence of fire Emory oak will probably attain the status of co-dominant.

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Appendix

Common and scientific names of plants mentioned and adaptation to fire.

Common name	Scientific name	Adaptation to fire
Trees		
Alligator juniper	*Juniperus deppeana*	sprouts from root crown
Arizona cypress	*Cupressus arizonica*	seed cones opened
Arizona oak	*Quercus arizonica*	sprouts from root crown
Canyon live oak	*Quercus chrysolepis*	sprouts from root crown
Emory oak	*Quercus emoryi*	sprouts from root crown
Gambel oak	*Quercus gambelii*	sprouts from root crown
Lowell ash	*Fraxinus lowellii*	sprouts from root crown
New Mexico locust	*Robinia neomexicana*	sprouts from root crown
One-seed juniper	*Juniperus monosperma*	none
Pinyon	*Pinus edulis*	none
Ponderosa pine	*Pinus ponderosa*	thick bark provides considerable protection
Shrubs		
Baker serviceberry	*Amelanchier bakeri*	sprouts from root crown
Birchleaf mountain-mahogany	*Cercocarpus betuloides*	sprouts from root crown
California buckthorn	*Rhamnus californica*	sprouts from root crown
Catclaw	*Acacia greggii*	sprouts from root crown
Catclaw mimosa	*Mimosa biuncifera*	sprouts from root crown
Chamise	*Adenostoma fasciculatum*	sprouts from root crown
Datil yucca	*Yucca baccata*	weak sprouter
Deerbrush	*Ceanothus integerrimus*	sprouts from root crown
Desert ceanothus	*Ceanothus greggii*	weak sprouter-reproduces prolifically from seed following fire, germination stimulated by fire
Engelmann pricklypear	*Opuntia engelmannii*	none
Falsemesquite	*Calliandra eriophylla*	sprouts from root crown
Hairy mountainmahogany	*Cercocarpus breviflorus*	sprouts from root crown
Hollyleaf buckthorn	*Rhamnus crocea*	sprouts from root crown
Littleleaf krameria	*Krameria parvifolia*	sprouts from root crown
Netleaf hackberry	*Celtis reticulata*	sprouts from root crown
Palmer oak	*Quercus dunnii*	sprouts from root crown
Parry agave	*Agave parryi*	none
Pointleaf manzanita	*Arctostaphylos pungens*	reproduces prolifically from seeds which require heat scarification to germinate
Pringle manzanita	*Arctostaphylos pringlei*	as pointleaf manzanita
Redberry algerita	*Berberis haematocarpa*	sprouts from root crown
Sacahuista (beargrass)	*Nolina microcarpa*	sprouts from root stock
Scrub oak	*Quercus dumosa*	sprouts from root crown
Shrub live oak	*Quercus turbinella*	sprouts from root crown
Skunkbush	*Rhus trilobata*	sprouts from root crown
Soaptree yucca	*Yucca elata*	none
Sugar sumac	*Rhus ovata*	sprouts from root crown
Wheeler sotol	*Dasylirion wheeleri*	none
Wright silktassel	*Garrya wrightii*	sprouts from root crown

Common name	Scientific name	Adaptation to fire
Yellowleaf silktassel	*Garrya flavescens*	sprouts from root crown
Yerbadepasmo baccharis	*Baccharis pteronioides*	sprouts from root crown
Yerbasanta	*Eriodictyon augustifolium*	reproduces from seed and prolifically by sprouting from shallow lateral roots
Half-Shrubs		
Broom menodora	*Menodora scoparia*	
Broom snakewood	*Gutierrezia sarothrae*	
California brickellia	*Brickellia californica*	
Feather dalea	*Dalea formosa*	
Purple nightshade	*Solanum xantii*	
Rough menodora	*Menodora scabra*	
Shrubby deervetch	*Lotus rigidus*	
Wright buckwheat	*Eriogonum wrightii*	
Forbs		
Aster	*Aster* spp.	
Bluedicks	*Dichelostemma pulchellum*	
Buckwheat	*Eriogonum* spp.	
Dark spurge	*Euphorbia melanadenia*	
Fleabane	*Erigeron* spp.	
Mustard	Family *Cruciferae*	
Penstemon	*Penstemon* spp.	
Redstar morningglory	*Ipomoea coccinea*	
Grasses		
Blue grama	*Bouteloua gracilis*	
*Boer lovegrass	*Eragrostis chloromelas*	
Cane bluestem	*Andropogon barbinodis*	
Green sprangletop	*Leptochloa dubia*	
Hairy grama	*Bouteloua hirsuta*	
*Lehmann lovegrass	*Eragrostis lehmanniana*	
Muhly	*Muhlenbergia* spp.	
Needlegrama	*Bouteloua aristidoides*	
Plains lovegrass	*Eragrostis intermedia*	
Red brome	*Bromus rubens*	
Sideoats grama	*Bouteloua curtipendula*	
Sixweeks grama	*Bouteloua barbata*	
Three awn	*Aristida* spp.	
*Weeping lovegrass	*Eragrostis curvula*	
Witchgrass	*Panicum capillare*	
Wolf tail	*Lycurus phleoides*	

**Introduced by seeding*

Carmichael, R. S., O. D. Knipe, C. P. Pase, and W. W. Brady. 1978. Arizona chaparral: Plant associations and ecology. Res. Pap. RM-202, 16 p. Rocky Mt. For. and Range Exp. Stn., For. Serv., U. S. Dep. Agric., Fort Collins, Colo. 80521.

Plant associations within the Arizona chaparral were delineated by a hierarchical classification using a diversity change index. Climax associations are mountainmahogany (birchleaf or hairy) - mixed shrub, shrub live oak - hairy mountainmahogany, shrub live oak-birchleaf mountainmahogany, shrub live oak-mixed shrub, Arizona cypress-shrub live oak, and Arizona oak-yellowleaf silktassel-Emory oak. Fire induced climax associations are shrub live oak-datil yucca-yellowleaf silktassel, pointleaf manzanita, Pringle manzanita, and yerba-santa-desert ceanothus.

Keywords: Arizona chaparral, climax vegetation, shrublands, plant associations.

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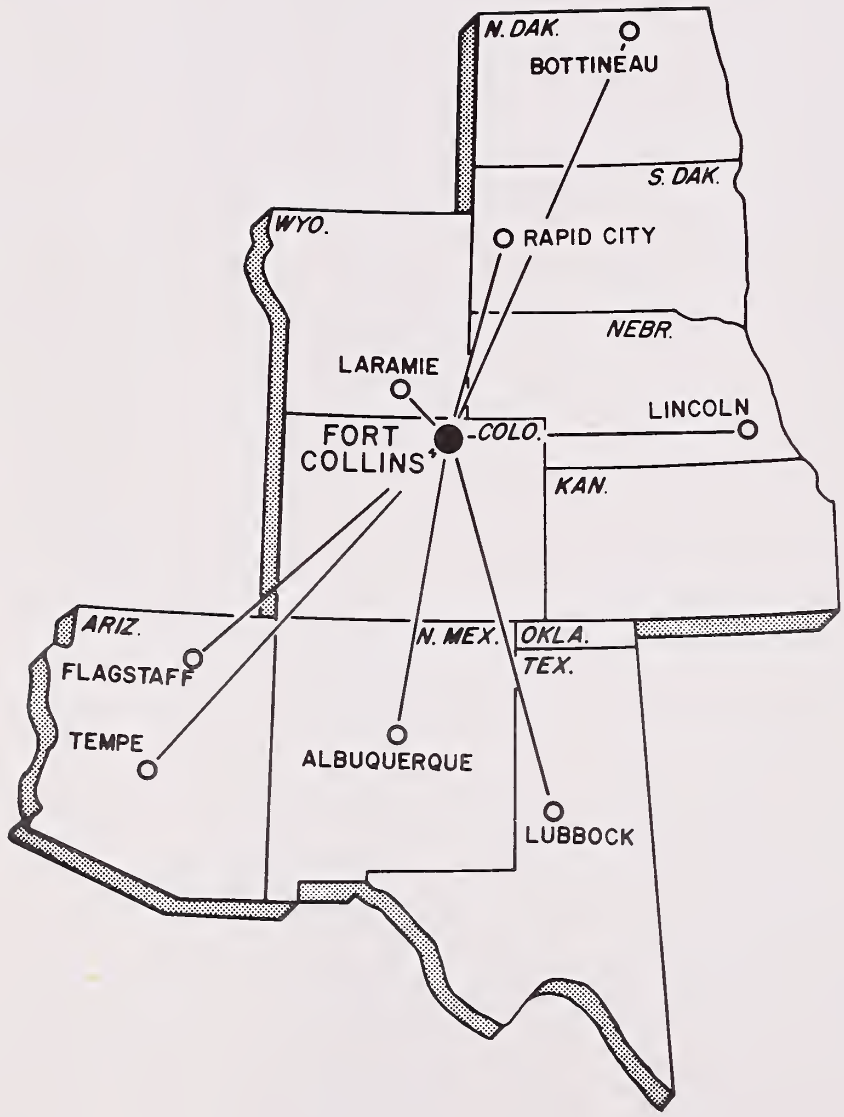
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